OPERATIVE MANAGEMENT OF CALCANEAL FRACTURES WITH TENTACLE PLATE
A SHORT-TERM PROSPECTIVE OUTCOME ANALYSIS

Dissertation submitted to

M.S. DEGREE-BRANCH II

ORTHOPAEDIC SURGERY

THE TAMILNADU DR.M.G.R.MEDICAL UNIVERSITY

CHENNAI-TAMILNADU

APRIL 2012

CERTIFICATE

This is to certify that this dissertation titled **"OPERATIVE MANAGEMENT OF CALCANEAL FRACTURES WITH TENTACLE PLATE A SHORT-TERM PROSPECTIVE OUTCOME ANALYSIS "** is a bonafide record of work done by **DR. N. SIVAKUMAR,** during the period of his Post graduate study from June 2009 to May 2012 under guidance and supervision in the Institute of ORTHOPAEDICS AND TRAUMATOLOGY, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-600003, in partial fulfilment of the requirement for **M.S.ORTHOPAEDIC SURGERY** degree Examination of The TamilnaduDr. M.G.R. Medical University to be held in April 2012.

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DECLARATION

I declare that the dissertation entitled **"OPERATIVE MANAGEMENT OF CALCANEAL FRACTURES WITH TENTACLE PLATE A SHORT-TERM PROSPECTIVE OUTCOME ANALYSIS "**submitted by me for the degree of M.S is the record work carried out by me during the period of **October 2009 to October 2011** under the guidance of **Prof**. **M.R. RAJASEKAR. M.S.Ortho.,D.Ortho.,** Professor of Orthopaedics, Institute of Orthopaedics and traumatology, Madras Medical College, Chennai. This dissertation is submitted to the TamilnaduDr.M.G.R. Medical University, Chennai, in partial fulfilmentof the University regulations for the award of degree of M.S.ORTHOPAEDICS (BRANCH-II)) examination to be held in April 2012.

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ACKNOWLEDGEMENT

I express my thanks and gratitude to our respected Dean Prof**. KANAGASABAI M.D.,** Madras Medical College, Chennai – 3 for having given permission for conducting this study and utilize the clinical materials of this hospital.

I have great pleasure in thanking my teacher and guide, **Prof. M.R.RAJASEKAR M.S, Ortho.,D.Ortho**.Director, Institute of Orthopaedics and Traumatology, for this valuable advice and guidance.

My sincere thanks and gratitude to**, Prof. Prof. N. DEEEN MUHAMMED ISMAIL. M.S. Ortho., D. Ortho**. Additional Professor, Institute Of Orthopaedics and Traumatology, for his constant advice and guidance provided throughout this study.

My sincere thanks and gratitude to**, Prof. V. SINGARAVADIVELU. M.S. Ortho., D. Ortho**. Additional Professor, Institute Of Orthopaedics and Traumatology, for his constant advice and guidance provided throughout this study.

My sincere thanks and gratitude to **Prof. A. PANDIASELVAM. M.S. Ortho., D. Ortho**.Additional Professor, Institute Of Orthopaedics and Traumatology, for his valuable advice and guidance.

I am very much grateful to **Prof. R. SUBBIAH.M.S.Ortho., D.Ortho**, for his unrestricted help and advice throughout the study period.

I sincerely thank**Prof. NALLI R. UVARAJ .M.S.Ortho**., **D.Ortho.**for his advice, guidance and unrelenting support during the study.

My sincere thanks to**Prof. R.H. GOVARDHAN.M.S,Ortho., D.Ortho**., former director**, Prof. S.SUBBAIAH., M.S,Ortho., D.Ortho**., and **Prof.V.THULASIRAMANM.S,Ortho., D.Ortho.,** retired professors, Institute Of Orthopaedics and Traumatology, for their valuable advice and guidance.

I sincerely thank **Dr. R. SELVARAJ M.S.Ortho., D.Orth**o. and **Dr. Antony Vimal Raj** M.S. Ortho. for their advice, guidance and unrelenting support during the study.

My sincere thanks and gratitude to my guides, **Dr. Shanmuga Sundaram M.S. Ortho.,** Additional Professor,**Dr. Manimaran M.S.Ortho**, and **Dr. Karunakaran.M.S.Ortho.,** for their constant advice and guidance provided throughout this study.

I sincerely thank**Dr.Muthazhagan, Dr.Nalli R. Gopinath, Dr.Hemanth Kumar, Dr. Senthil Sailesh Dr. Velmurugan, Dr. Kingsly, and Dr. Prabhakaran. Dr. Shanmuga Sundram, Dr. T.R. RameshPandian, Dr. N.B. Thanmaran, Dr. Manimaran, Dr. Pazani, Dr. Muthukumar, Dr. Kannan**, **Dr. Sameer** Assistant Professors of this department for their valuable suggestions and help during this study.

I thank all anaesthesiologists and staff members of the theatre for their endurance during this study.

I am grateful to all my post graduate colleagues for helping in this study. Last but not least, my sincere thanks to all our patients, without whom this study would not have been possible.

CONTENTS

INTRODUCTION

Calcaneal fractures are the most common fracture of the tarsal bones, yet controversy still exists on the best treatment for these disabling injuries [2, 9, 15, 16, and 20]. However, as a better understanding of fracture patterns with computed tomography scans and modern surgical techniques and hardware has improved outcomes and lowered morbidity, a trend has developed toward open reduction and internal fixation (ORIF) for displaced, intra-articular calcaneus fractures [2, 4, 6, 9, 16, 27].

Calcaneal fractures often results in a varus deformity with heel widening, loss of calcaneal height, and subtalar joint incongruency. Open reduction and internal fixation can be used to address deformities, restoring the anatomic morphology of the calcaneus, and thereby the biomechanics and function of the hindfoot. Restoring heel width prevents chronic peroneal tendenitis secondary to impingement from lateral wall blowout of the calcaneus, and restoring the length and alignment of the Achilles tendon maintains plantar flexion strength [16, 20, 27]. Open Reduction & Internal Fixation also provides the opportunity for anatomic reduction and rigid internal fixation of the subtalar joint. Normal subtalar motion is integral for the foot to adapt on uneven surfaces with inversion and eversion.

Plate osteosynthesis of the intra-articular fractures is a standard treatment method, but it has potential complications such as poor wound healing and infection. Calcaneal shape restoration by means of open reduction internal fixation (ORIF) or primary subtalar arthrodesis if needed is mandatory prevention of late complications such as malposition, flattening of the longitudinal arch, anterior ankle impingement syndrome, lateral impingement syndrome, and axial malalignment of the hind foot.[1]

AIM OF THE STUDY

This is a prospective cohort study to evaluate the results of open reduction through an extensile lateral approach and internal fixation with calcaneal tentacle plate as surgical treatment of the displaced intra-articular calcaneal fracture.

HISTORICAL REVIEW

Fractures of the calcaneus, or os calcis, have been observed and documented for centuries. Norris correctly described a compression mechanism in calcaneus fractures in 1839, and in 1843, Malgaigne described 2 types of calcaneal fractures; this description formed the first rudimentary classification system.

With the advent of radiographic evaluation, several authors developed classification systems, including Bohler (in 1931), Essex-Lopresti (in 1951-2), Rowe et al (in 1963), and others. Essex-Lopresti first sought to distinguish intra-articular fractures of the calcaneus from extra-articular ones, and they correctly associated the intra-articular variety with a poorer long-term prognosis.

1988 French SOFCOT symposium on Intra-articular calcaneal fractures emphasized the indications for surgery on radiological stages. From 2003, management of displaced calcaneal fractures are performed regardless of the radiological stage by extended lateral approach[17,19].

FUNCTIONAL ANATOMY

In humans, the calcaneum is the largest of the tarsal bones and the largest bone of the foot.

The posterior half of the bone is the tuber calcanei. On its lower edge on either side are its lateral and medial processes (serving as the origins of the abductor hallucis and abductor digit minimi).

The Achilles tendon is inserted into a roughened area on its superior side, the cuboid bone articulates with its anterior side, and on its superior side are three articular surfaces for the articulation with the talus bone. Between these superior articulations and the equivalents on the talus is the tarsal sinus (a canal occupied by the interosseous talocalcaneal ligament).

On the medial side of the bone, below the middle talar facet is the sustentaculum tali (which serves for the attachment of several other ligaments).

On the lateral side is commonly a tubercle called the peroneal trochlea, under which is a groove for the tendon of the peroneus longus.

In the calcaneum, an ossification center is developed during the 4-7th intrauterine month.

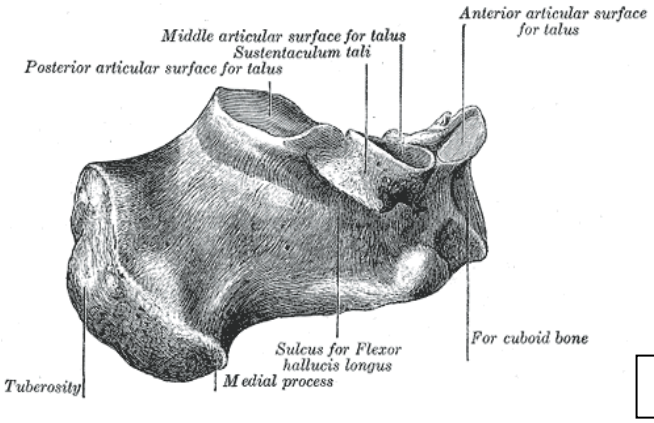


Fig.1 A

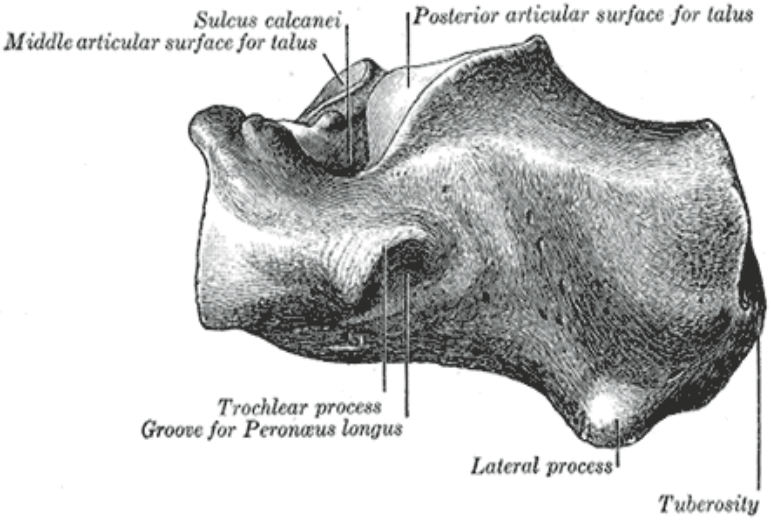


Fig. 1B

The calcaneus is composed of sparse trabeculae bounded by a thin shell of cortical bone. The tuberosity constitutes the posterior half of the bone (Fig. 1 A, B). The anterior half serves as a support for the talus and contains the anterior, medial, and posterior facets [1, 8, 16]. The posterior facet, which is the largest, is situated superiorly in the mid-body of the calcaneus and slopes downwards and anteriorly towards the anterior

process. The smaller medial and anterior facets are often confluent and occupy a broad bony projection called the sustentaculum tali, arising from the medial surface of the calcaneus. The anterior and medial articulating facets are often difficult to differentiate from each other. Occasionally, the anterior is visualized slightly more distal to the other facets, occupying a more horizontal plane. The peroneal tendons are easily identified posterior to be lateral malleolus of the fibula, paralleling the lateral wall of the calcaneus. Their close proximity to the bone explains the commonly associated post-traumatic peroneal tenosynovitis [5,17]. The calcaneo-cuboid joint is identified anterolaterally.

- ***Blood supply of calcaneus:***

Blood supply of calcaneus is derived from medial and lateral calcaneal arteries. The medial calcaneal artery arises from posterior tibial artery while the lateral calcaneal artery arises from peroneal artery. There is also some degree of blood supply coming from peroneal artery, posterior calcaneal anastomosis, medial and lateral plantar arteries**.**

- ***Nerve supply to calcaneus:***

The calcaneus receives its nerve supply by branches of the tibial, sural and the deep peroneal nerves**.**

- ***Ossification of calcaneus:***

Calcaneus is the only tarsal bone, which has two centers of ossification. The main center appears prenatally in the third month. The second center appears in the sixth year and fuses in fourteenth year. This center covers most of posterior surface and a part of plantar surface.

- ***Ligaments and membranes***

- The main ligament of the joint is the interosseous talocalcaneal ligament, a thick, strong band of two partially joined fibers that bind the talus and calcaneus. It runs through the sinus tarsi, a canal between the articulations of the two bones.

- There are four additional ligaments that form weaker connections between the talus and calcaneus.

- The anterior talocalcaneal ligament (or anterior interosseous ligament) attaches at the neck of the talus on the front and lateral surfaces to the superior calcaneus.

- The short band of the posterior talocalcaneal ligament extends from the lateral tubercle of the talus to the upper medial calcaneus.

- The short, strong lateral talocalcaneal ligament connects from the lateral talus under the fibular facet to the lateral calcaneus, and runs parallel to the calcaneofibular ligament (Fig.2)

- The medial talocalcaneal ligament extends from the medial tubercle of the talus to the sustentaculum tali on the medial surface of the calcaneus.

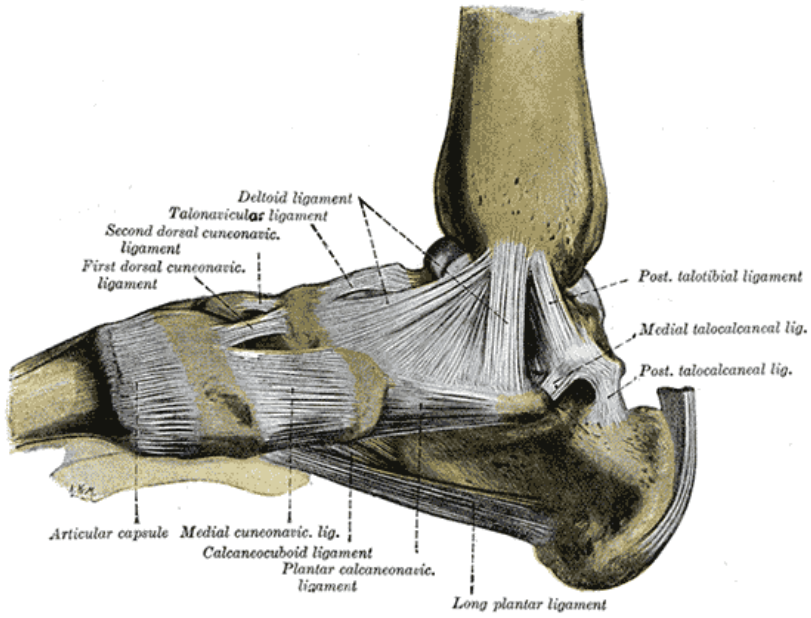


Fig.2

Calcaneal Angles:

Radiograph showing traction trabeculae radiating from the inferior cortex of the calcaneus and compression trabeculae converging to support the posterior and anterior articular facets. The area between these trabeculae is known as the neutral triangle (Fig.3)

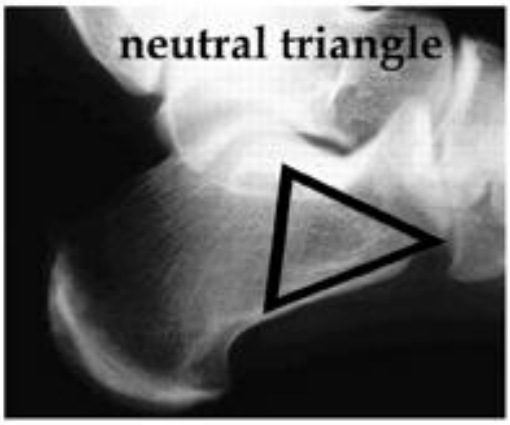


Fig.3

Two important angles are seen on the lateral radiograph of the calcaneus. The tuber angle of Böhler, usually between 20 and 40 degrees, is formed by two lines. The first line is drawn from the highest point of the anterior process of the calcaneus to the highest point of the posterior facet. The second line runs tangential to the superior edge of the tuberosity (Fig.4). A decrease in this angle may indicate that the weight-bearing surface of the calcaneus (the posterior facet) has collapsed, shifting the weight of the body anteriorly.

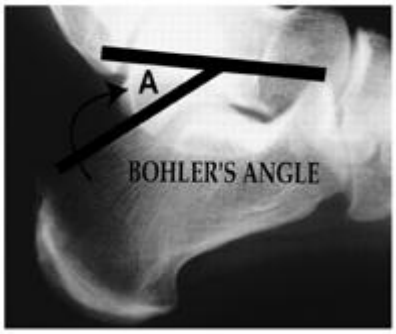


Fig.4

The second angle, the crucial angle of Gissane, is seen directly inferior to the lateral process of the talus and is represented by two strong

cortical struts that extend laterally and form an obtuse angle. The first strut extends along the lateral border of the posterior facet, and the second extends anteriorly to the beak of the calcaneus (Fig. 5)

Fig.5

BIO-MECHANICS

Mechanism of injury:

Intraarticular fractures account for approximately 75% of calcaneal fractures and historically have been associated with poor functional outcome. These fractures are uniformly caused by an axial load mechanism, such as a fall or a motor vehicle accident, and may be associated with other axial load injuries, such as lumbar spine, cervical spine, pelvic, and tibial plateau fractures.

The contact point of the calcaneus is situated lateral to the weight bearing axis of the lower extremity. As an axial load force is applied to the posterior facet of the calcaneus through the talus, shear forces are directed through the posterior facet toward the medial wall of the calcaneus.

The ensuing fracture (primary fracture line) is almost always present and extends from the proximal, medial aspect of the calcaneal tuberosity, through the anterolateral wall, usually in the vicinity of the crucial angle of Gissane. The most variable aspect of this fracture line is its position through the posterior facet of the calcaneus; it can be located in the medial third near the sustentaculum tali, the central third, or the lateral third near the lateral wall.

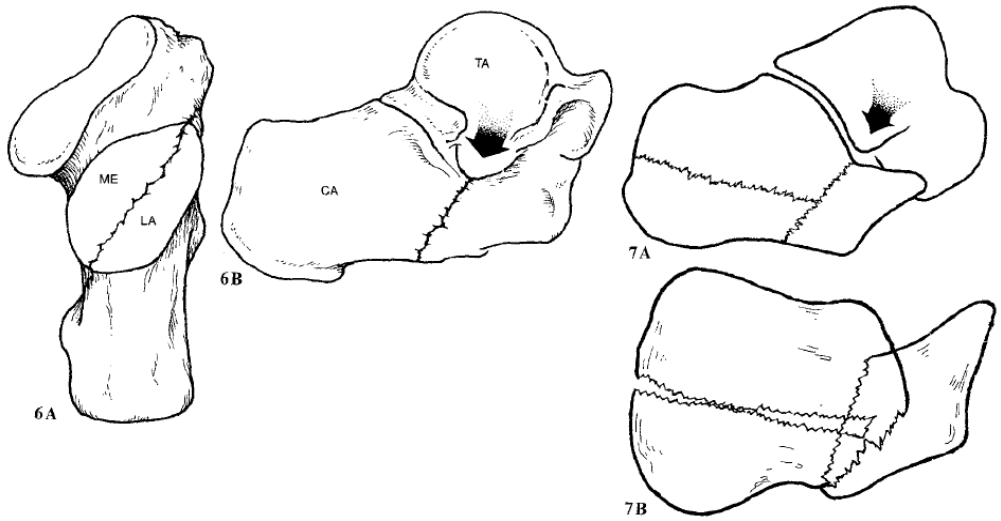


Fig.6 Mechanism of injury – primary fracture line. Calcaneus is split into medial and lateral fragments. **A** Dorsal and **B** lateral view. [CA – Calcaneus, ME- anteromedial fragment, LA – posterolateral fragment, TA – talus]

Fig.7 Mechanism of injury – tongue type fracture. Lateral view of **A** nondisplaced and **B** displaced calcaneal fragments.

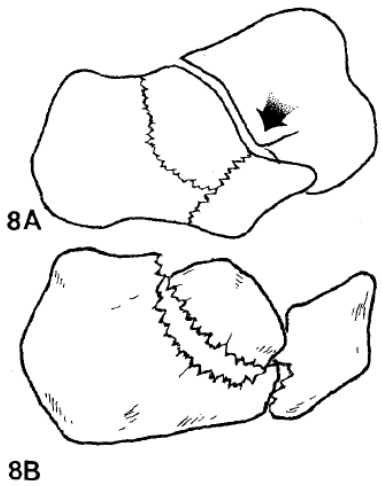


Fig.8 Mechanism of injury – joint depression type fracture. Lateral view of **A** nondisplaced and **B** displaced calcaneal fragments.

Biomechanics of plate:

Calcaneal tentacle plate (Fig. 9) has an anatomical shape corresponding to the anatomy of the calcaneus. It is available in three different sizes, to better fit the calcaneus shape (5.5 cm long for size small, 6.5 cm long for size medium and 7.5 cm long for size large). Its thickness is 1 mm in the middle, and 1.80 mm in the sites of main fixation. 3-4 holes are present in its anterior, posterior and upper parts for fixation screws with threaded heads, and 9-10 holes for variable orientation of the screws. The plate is fixed using 3.5 mm screws. Holes in the plate provide fixation with up to 4 screws in the posterior tuberosity, 3 screws in the anterior process, and 7 screws in the middle. The limited thickness permits to mould the plate and to eventually cut it if the plate is overstuffing anatomically the calcaneus. The upper part of the posterior and anterior borders can sometimes be cut off, or bent for a dorso-plantar screw fixation. Before the definitive fixation of the plate, autologous or synthetic bone grafts may be inserted, if necessary, in the os trigonum of the calcaneus.

Fixation of Calcaneal tentacle plate in a good cortical area of the lateral calcaneal wall improves the mechanical resistance of the implant. The plate exerts a compression effect when screws are tightened, reducing the width of the posterior tuberosity. Therefore, it allows the connection of the thalamus portion to the inferior segment. This improved mechanical resistance may make it possible to reduce the period of partial weight bearing after the operation.

Advantages:

- Increased stability by locking screw fixation and "bridging" of the primary fracture line
- Low profile plate
- Thickness allows remodelling according to the lateral wall of the calcaneus
- Low irritation of soft tissues and tendons
- Reconstruction of height and width of the calcaneus
- Large number of holes for versatile fixation
- Dual screw fixation system (locking & variable) allowing stable fixation regardless of bone conditions

- Angulation of the screws up to 30°

- Bi-cortical or mono-cortical fixation

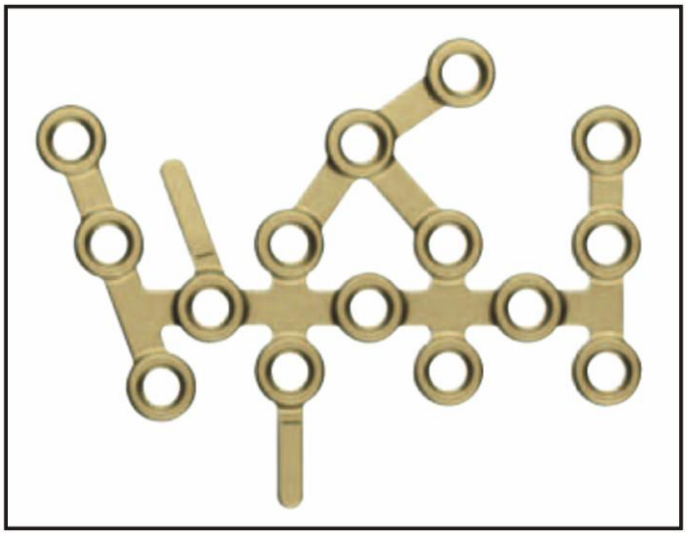


Fig. 9

MATERIALS & METHODS

Total no. of 25 cases with calcaneal fracture, admitted between march 2009 to march 2011 in Rajiv Gandhi Govt. General Hospital, Chennai, were included in the study. All the cases were operated and followed up by using single protocol with regard to extensile lateral approach, surgical techniques, pre-op & post-op evaluation.

Inclusion & exclusion criteria for surgery as follows :

Inclusion criteria:

- Age more than 16 years
- Occupation of the patient (laborer, tailor)
- Bohler's angle $< 20^{o}$
- Gissane's angle $>115^{o}$
- Sander's type II, III and IV

Exclusion criteria:

- Fractures > 4 weeks
- Sander's type I calcaneal fracture
- Extra articular fractures
- Patients with other medical problems

General data:

Among the twenty five cases, 19 cases were men and 6 cases were women. Mean age of the patient at the time of presentation was 32.2 years (range 18 to 60 yrs). Majority of them were male – 76%

History of accidental fall from height predominate the series by 72% (18 cases). Other mode of violence was road traffic accident & polytrauma.

40% of the cases presented with associated injuries (spinal injury, pelvic fractures, multiple fractures, ipsilateral lower limb injury).

Pre Op X-ray Assessment:

At the time of admission to the hospital, anteroposterior, lateral, axial, and internal oblique radiographs of the fractured calcaneus and oblique radiographs of the injured foot as well as lateral and axial(harrison's view) radiographs of the normal calcaneus were taken. A pre-operative CT scan was taken for all cases to obtain better appreciation of the size of the displaced fracture fragments and the number of fracture lines that had to be identified and surgically reduced.

From the radiographs and CT scan, the type of fracture was determined, and the pre-operative Bohler's angle, and calcaneal height and width were measured.

Classification:

With increasing use of CT, more complex classification systems have been developed for these fractures that have been shown to have prognostic value in the treatment of these injuries.

Although the Essex-Lopresti system has been used for many years and is useful in describing the location of the secondary fracture line, it does not describe the overall energy absorbed by the posterior facet, shown by comminution or displaced fragments

Classification systems by Crosby and Fitzgibbons and Sanders have become more widely accepted in evaluation of these fractures [8]. Both classifications are based on CT scans and describe comminution and displacement of the posterior facet. The advantage of the Sanders classification is its precision regarding the location and number of fracture lines through the posterior facet [23]. Both systems lack descriptions of other important aspects of these fractures, however,

including heel height and width, varus-valgus alignment, and calcaneo cuboid involvement.

In our study we have used Sander's classification to classify the fracture pattern (Fig. 10).

SANDER'S CLASSIFICATION:

(CT classification of intraarticular calcaneal fractures)

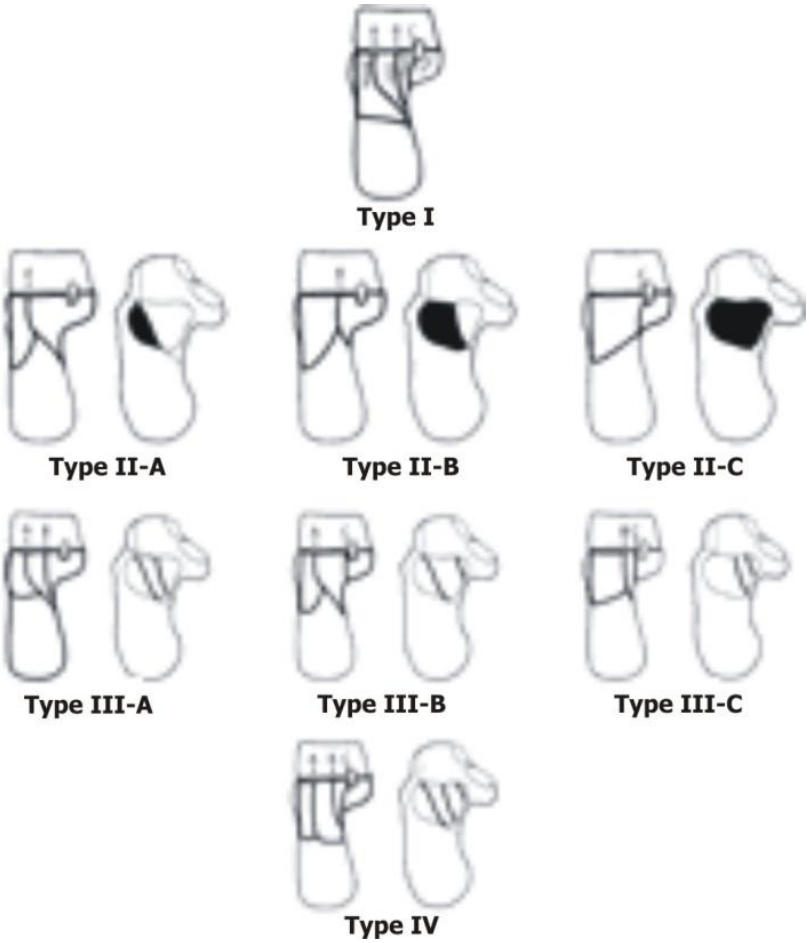


Fig. 10

Preparation for Surgery:

Mean interval for surgery is 15 +/- 6 days (range 10-30 days).

Operation was planned according to type of fracture, whether displaced or undisplaced, severity of comminution, skin status (blisters), open or closed fracture, & edema regression.

According to the fracture pattern and comminution, number and positioning of the screws, bone graft to be used or not, were planned.

Edema regression is encouraged by bed rest, limb elevation, compressive bandage & anti-inflammatory drugs.

Operative Procedure:

- The patient is positioned in lateral decubitus position
- Safe support is needed so that the table can be tilted for fluoroscopy or for an additional reduction manoeuvre
- The landmarks for incision are the distal fibula, the anterior process of the calcaneus, the calcaneo cuboid joint and the base of the 5th metatarsal
- A large L-shaped (right side) or J-shaped (left side) surgical incision is made beginning approximately 4 cm above the tip of the

lateral malleolus, midway between the posterior border of the fibula and the Achilles tendon

- The lateral incision allows direct access and easier reduction of the displaced lateral fragment, compared to medial approach

Fig.11

- The incision begins proximally, curves below the sural nerve, and then moves upward to the calcaneo cuboid joint.
- It is imperative to avoid harming the sural nerve and prevent skin flap difficulties (Fig.11)

The incision is made down to the bone in order to make a cutaneous – subcutaneous flap that includes the peroneal tendons. The flap is developed anteriorly to expose the posterior subtalar joint.

- The flap is elevated, along with the sural nerve and peroneal tendons (Fig.12)

- Pins are then inserted and bent to hold the flap and the soft tissues

Fig. 12

- The subtalar joint is opened and the fractures of the lateral calcaneal wall are dissected, in order to expose the fractured and depressed articular fragments

- The reduction manoeuvre usually begins at the posterior articular surface and proceeds to the Gissane angle and to the body of the calcaneus. However, if varus tilt of the calcaneus prevents anatomic reduction of the posterior facet, the alignment of the body may need to be corrected prior to the reduction of the joint surface.

Various reduction techniques were performed by pulling lateral cortical wall, greater tuberosity depression, medial thalamic portion raising, and lateral thalamic wall reduction to the medial portion, the greater apophysis reconstruction & finally lateral wall repositioning (Fig.13).

Temporary reduction is maintained by 1.5 k-wires, & bone graft was done in those cases (56%) with severe comminution.

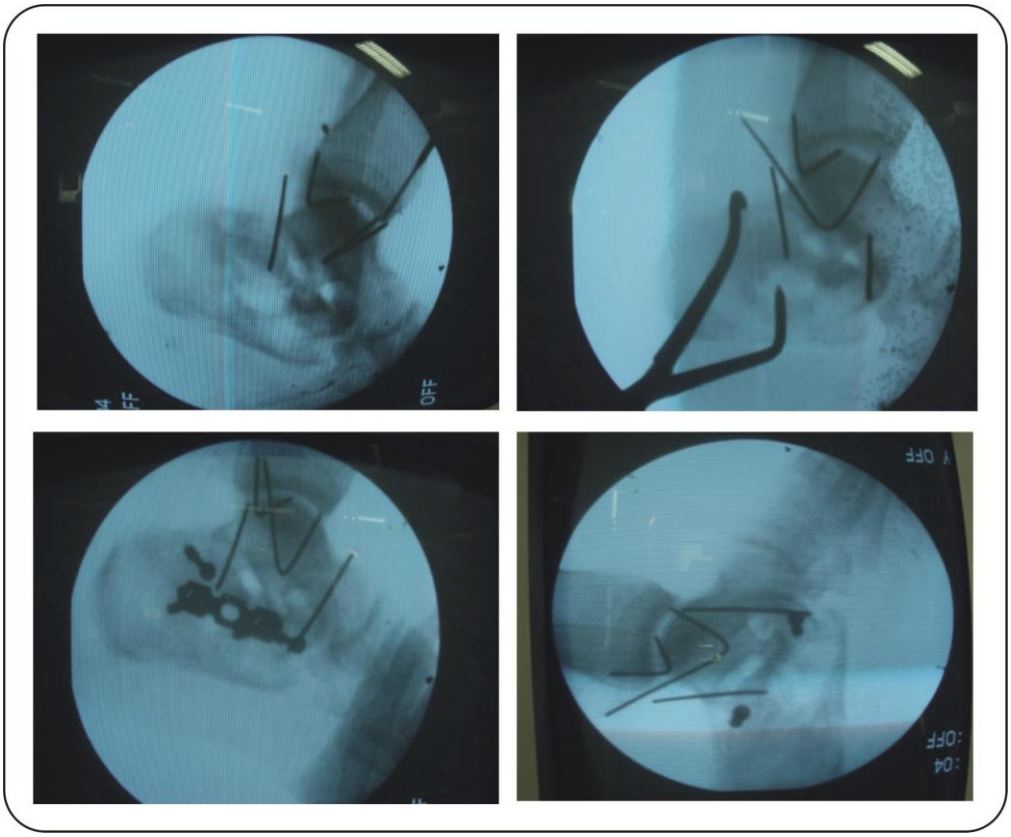


Fig. 13

Three areas of dense cortical bone will hold fixation well:

- distal portion of the calcaneus (near the calcaneo cuboid joint),
- below the angles of Gissane (below the posterior facet),
- the tuberosity

A triangle of soft cortical bone in the middle portion of the calcaneus is a neutral triangle that will not hold a screw well.

- At this point, the Calcaneal tentacle plate is used
- The size that best fits the calcaneal anatomy is chosen: size small, medium or large

  Each plate is anatomical and suitable for either left or right side

1. The Calcaneal tentacle plate is then positioned at the appropriate location on the lateral calcaneal wall
2. If necessary the Calcaneal tentacle plate can be moulded and contoured to the lateral aspect of the anterior process, the posterior facet and to the tuberosity
3. The upper part of the posterior and anterior borders can sometimes be cut off, or be bent for a dorso-plantar screw fixation
4. Plate benders should be used for this bending procedure

The drilling sleeves are first screwed in the hole located on the anterior extremity and in the 2 holes on the posterior extremity of the plate (Fig. 14).

Fig.14

- They allow axial drilling and perfect insertion of the screws
- The holes for fixation screws are drilled using the 2.7 mm drill through the drilling sleeves
- The plate is fixed using specific 3.5 mm screws
- Holes in the plate allow fixation with up to 3 screws in the posterior tuberosity, and 2 screws in the anterior process.
- If there is a fracture of the anterior process of the calcaneus, it will be temporarily stabilized with Kirschner wires

- The screws are inserted with the specific screwdriver in a normal way, and introduced in the bone until the base of their head is blocked against the plate

- The appropriate length of the screws to be inserted is evaluated using the depth gauge.

Before closure of the wound, the tourniquet was released, and haemostasis obtained. Skin closure done in layers. Crepe bandage and below knee slab were applied for all the cases.








Post-Op Protocol:

- Compression bandage & limb elevation in immediate post op period to reduce the edema. Below knee slab was applied for two weeks.
- Suture removal was done in 14th post operative day.
- After two weeks, ankle and subtalar joint mobilisation were started.

Follow Up:

Regular follow up of all the patients at monthly interval for first three months followed by three months interval were done. During the follow up period, subjective evaluation (patient satisfaction), clinical assessment (gait, healing), radiological assessment were done using Weber scoring system.

All the patients were taken radiographs in anteroposterior, lateral view and Harrison's axial view to assess radiological union, post operative Bohler's angle, calcaneal height, width, subtalar joint congruency.

- Minimum follow up period – 6 months
- Maximum follow up period -2 yrs

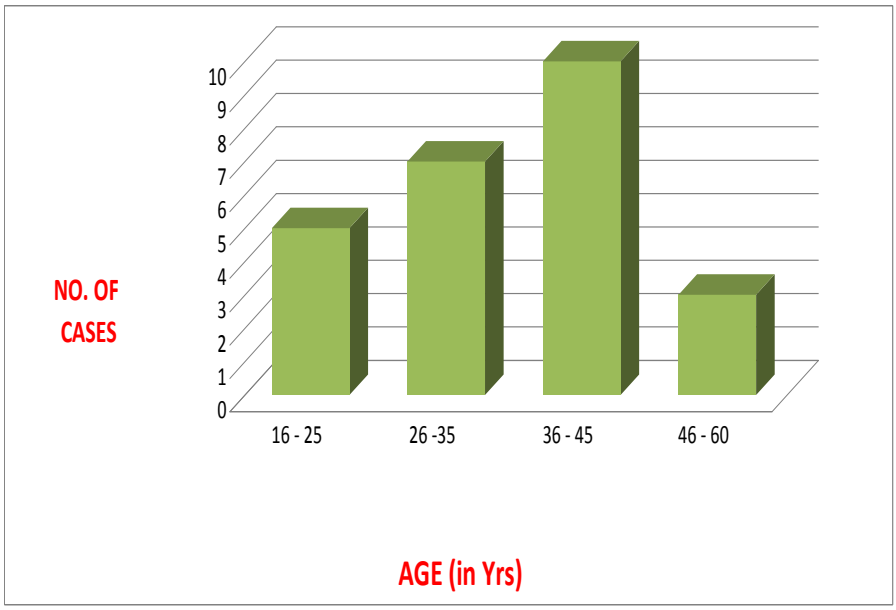
- Rehabilitation programme was same for all the patients
- 75% of people attended the rehabilitation center
- First 2 weeks –active & passive ankle joint and toe mobilisation was done.
- All the cases were treated with below knee slab for three weeks
- Active Subtalar inversion and eversion movements were started after three weeks.
- Non-wt bearing walking for 2 months, then gradual weight bearing allowed based on radiological union & pain tolerance.
- At the end of 3rd month, patient normal weight bearing was allowed.

OBSERVATION & RESULTS

In our series, five cases (20%) were in between the age group of 16-25 yrs, seven cases (28%) were in 26-35 yrs, ten cases (40%) were in 36-45 yrs and three cases were in 46-60 yrs. Among them, 19 cases (76%) were male and 6 cases (24%) were female (Table – 1).

Table. 1

Age Distribution	Cases
16-25 Yrs	5(20%)
26-35 Yrs	7(28%)
36-45 Yrs	10(40%)
46-60 Yrs	3(12%)



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History of accidental fall from height predominate the series by 72% (18 cases). Other mode of violence was road traffic accident & polytrauma.

40% of the cases presented with associated injuries (spinal injury, pelvic fractures, multiple fractures, ipsilateral lower limb injury).

Radiological Analysis:

In our series 8 (32%) cases were Sander's type –II fracture, 11 cases (44%) were Sander's type-III, and 6 cases (24%) were type IV. Bone grafting (allograft) was used in fourteen cases (56%) and not used in eleven cases (44%). Among them Bone graft was used in one case (4%) of type II fractures, seven cases (28%) of type III fractures and in six (24%) cases of type IV fractures (Table- 2).

Table. 2

Sander's Classification	Cases
TYPE – II	8(32%)
TYPE – III	11(44%)
TYPE – IV	6(24%)

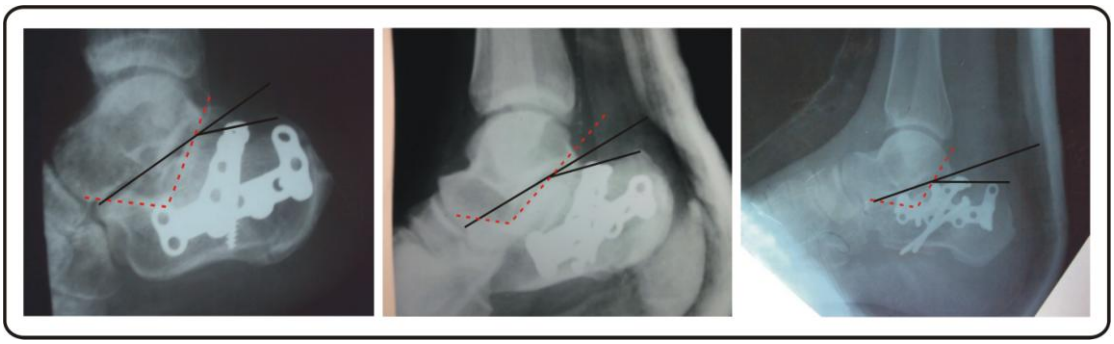
Pre operative Bohler's angle in the study group was between 10 ^{o} -20 ^{o} in 72**%** of cases and remaining 28% of cases had less than 10 ^{o} angles (average -14.6 ^{o}). Mean pre-operative Bohler's angle among type II fractures was 18.87 ^{o}, among type III fractures was 14.18 ^{o}, and among type IV fractures was 10^{o} (Table – 3). Post operatively Bohler's angle was corrected to 20 ^{o} -30 ^{o} in 84% of cases and 15 ^{o} -20 ^{o} in 16% of cases (average - 24.56 ^{o}). Mean post-operative Bohler's angle among type –II fractures was 28.25 ^{o}, among type III fractures was 22.54 ^{o} and among type IV fractures was 20^{o} (Table – 4). Mean pre-op calcaneal height was 38.6 mm (range 26 mm to 46 mm). Mean pre-op calcaneal height among type II fractures was 41.87 mm, among type III fractures was 40mm and among type IV fractures was 31.66 mm. Post operatively calcaneal height was corrected to an average of 49.64 mm (range – 44 mm to 56 mm). Mean post-op calcaneal height among type II fractures was 50.5 mm, among type III fractures was 50.81 and among type IV fractures was 46.33 mm.

Table. 3

Pre-Op Bohler's angle	**Cases**
10^o-20^o	18(72%)
< 10^o	7(28%)

Table. 4

Post-Op Bohler's angle	**Cases**
20^o to 30^o	**21 (84%)**
15^o to 20^o	**4 (16%)**



Pre operatively subtalar joint incongruence was present in 23 cases (92%). Post operatively Subtalar joint congruence was achieved in 19 cases (76%) and the remaining 6 cases (24%) had subtalar joint incongruency. Post operative subtalar joint incongruence present in 5 cases of type IV fracture and 1 case of type III fracture (Table – 5).

Posterior subtalar joint scoring in this series: [13, 14]

Table. 5

Grade	Articular Incongruity (mm step off)	No. of Cases
0	0-1	19 (76%)
1	1-2	6 (24%)
2	2-3	0
3	>3	0

Radiological union obtained in 96% of the cases (24 cases). And one case gone for non union because of osteomyelitis.

None of the patients had postoperative heel valgus/ varus deformity.

At an average of 11 months of follow up (6months to 2 yrs), 96% of the patients had no post-operative collapse of the calcaneal height and 4% (1 case) had post operative collapse of the calcaneal height because of infective implant loosening.

***Subjective & Functional Analysis*:**

In our study post operative functional analysis of the calcaneal fractures were done with Modified Weber's Ankle & Foot functional scoring system. This scoring system analyses the patients both subjectively and objectively. Subjective analysis includes pain, walking, activity and objective analysis includes radiographic evaluation, ankle joint & subtalar joint function.

Pain at the lateral aspect of heel was the main complain of the majority of patients. Nine cases (36%) had no pain at rest or activity. Eleven patients (44%) developed slight pain on lateral aspect of the foot on excess activity and the pain was tolerable and related to peroneal tendon irritation. Only five patients (20%) had pain on normal activity and the pain was related to subtalar joint incongruity. These five patients required mild analgesics to relief pain at rest.

Eighteen patients (72%) could walk and stand for unlimited time despite the presence of pain in nine of them. The remaining six patients (24%) had restriction of walking in strenuous activities and one patient (4%) had slight limping (Table – 6).

Post-op Weber scoring in this series:

Subjective

(Annexure – 1A)

Tabl3. 6

Pain		**Walking**		**Activity**	
Cases	**Score**	**Cases**	**Score**	**Cases**	**Score**
5 cases (20%)	2	1 case (4%)	2	1 case (4%)	2
11 cases (44%)	1	6 cases (24%)	1	5 cases (20%)	1
9 cases (36%)	0	18 cases (72%)	0	19 cases (76%)	0

76% of patients use normal foot wear and return to their job at average of 5 months. 20% of patients were able to work normally but were restricted in some activities, which necessitated slight modification in their work pattern. One case (4%) had very limited in activity and use protective orthosis. This patient had a type IV joint depression fracture, had a preoperative Bohler's angle of $<10^{o}$, and had the highest Weber's functional score.

But 96% of the patients received their work after 3 to 7 months (average – 5 months). None of our patients were sports related individuals.

Clinical Analysis

Scars had a satisfactory healing in 88% of cases (pain free) and 12% of cases had wound dehiscence which were treated with antibiotics & daily dressing. Swelling of the heel was a common subjective and objective finding which was mostly soft tissue in origin and took a long time (average 6 months) to resolve. Out of the twenty five patients included in this study, twenty patients (80%) had mild swelling and five patients (20%) had moderate swelling.

Ankle dorsiflexion, plantar flexion was identical to the opposite foot in 92% of cases and the remaining 8% of cases had ankle movement restriction. Subtalar joint inversion & eversion movements were near normal (average of 95% from normal) compared to the opposite foot in 76 % of cases and the remaining 24% of cases had subtalar joint restriction (average of 70% of normal) (Table -7).

Objective

(Annexure -1B)

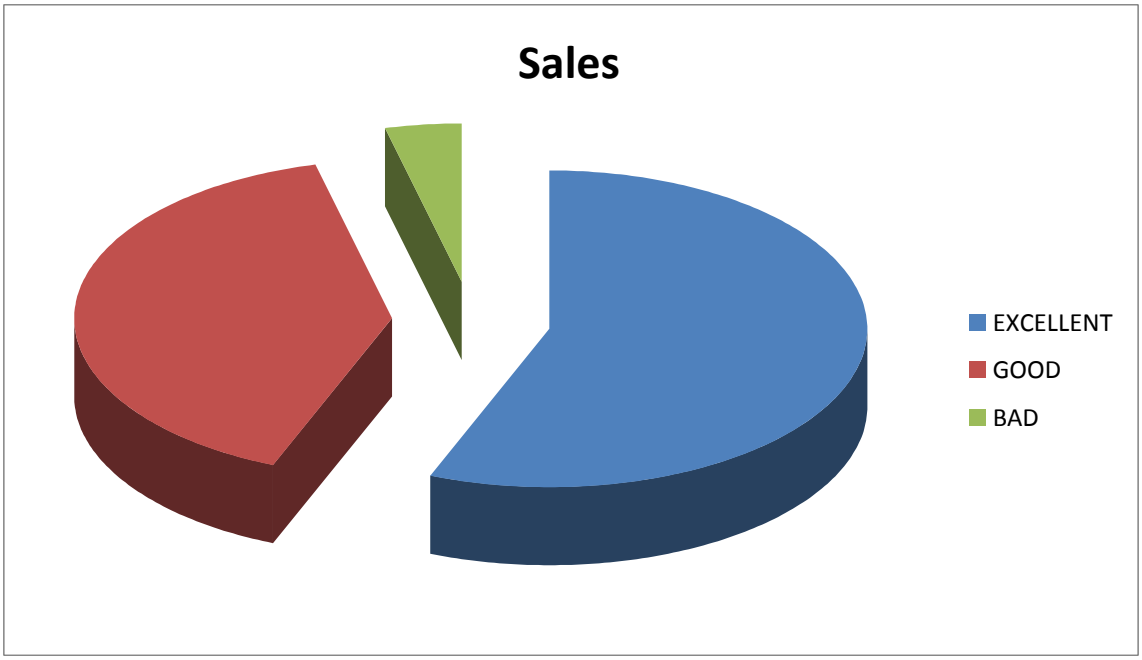
Table. 7

Radiograph		**Ankle joint function**		**Subtalar jt function**	
Cases	**Score**	**Cases**	**score**	**cases**	**Score**
24 cases (96%)	0	17 cases (68%)	0	10 cases (40%)	0
1 case (4%)	1	7 cases (28%)	1	9 cases (36%)	1
		1 case (4%)	2	6 cases (24%)	2

Among 25 patients operated, 14 patients (56%) were very much satisfied, 10 (40%) were satisfied & 1(4%) had a poor result. All type II (32%) fractures, 6 out of 11 cases (24%) in type III fractures had excellent results. 5 out of 11 cases (20%) in type III fractures and 5 out of 6 cases (20%) in type-IV fractures had good results. One type IV fracture had bad result (Table – 8)

Table. 8

Weber's score	Cases
Excellent	14(56%)
Good	10(40%)
Bad	1(4%)

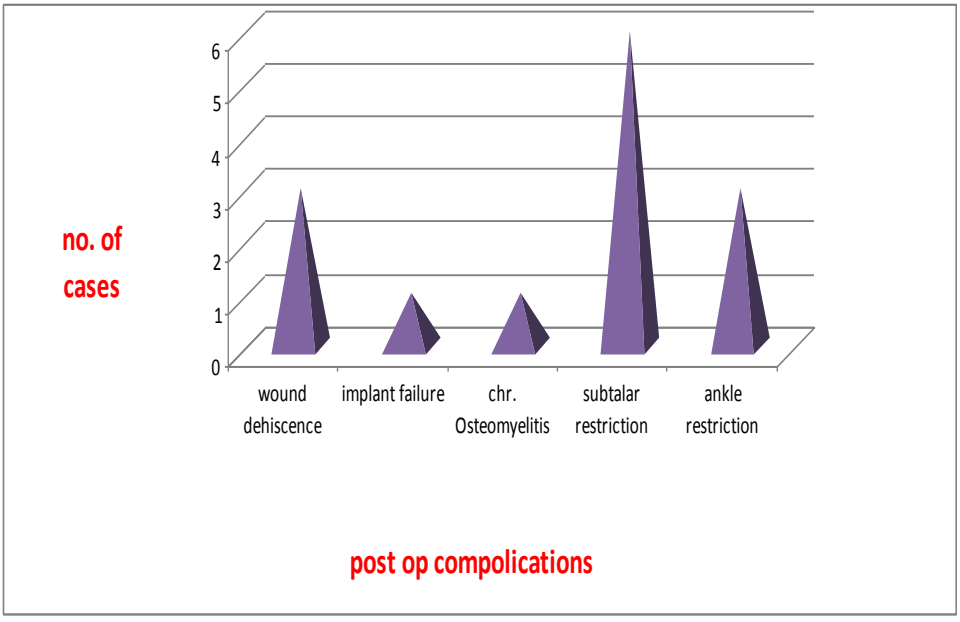


In our series, 6 cases developed subtalar joint restriction, 3 cases (12%) had wound dehiscence, 2 cases had ankle joint restriction, 1 case (4%) had osteomyelitis, and 1 case (4 %) had implant loosening (Table – 9).

Table. 9

Post-op Complications	Cases
Wound dehiscence	3(12%)
Osteomyelitis	1(4%)
Implant loosening	1(4%)
Ankle restriction	2(8%)
Subtalar restriction	6(24%)

WOUND DEHISCENCE



DISCUSSION

In our series, calcaneal fractures are more commonly occur in the middle age group (36-45 yrs) (35%). Males (76%) had sustained calcaneal fracture more commonly compared to females (24%).

History of accidental fall from height predominate the series by 72% (18 cases). 40% of the cases presented with associated injuries (spinal injury, pelvic fractures, multiple fractures, ipsilateral lower limb injury).

In our study Sander's type III fractures (44%) predominates the series, compared to type II (32%) and type IV (24%) and fall from height is the most common mode of injury(%). Joint depression type of intra-articular fracture type is the most common type in our series.

A biomechanical study of Perry [21] has confirmed the important role of the subtalar joint in relieving the ankle from rotational forces during walking. Without this relieving mechanism, the ankle may develop secondary degenerative arthritis. Fractures of the calcaneus with involvement of the subtalar joint are actually split-depressed fractures analogous to displaced fractures of the tibial plateau. Such fractures

should be treated like any other intra-articular fractures by anatomical reduction, absolute stable fixation, and early mobilization.

Stephenson [26] used a combined medial and lateral approach and found that the small lateral approach made it possible to reduce the posterior facet accurately under direct vision and to obtain secure fixation that allowed early subtalar motion. Also, by using the medial approach, an accurate reduction of the tuberosity fragment relative to the superomedial fragment was possible. Paley and Hall [20] used only the medial approach for all his cases and reported that this approach was not adequate to address the lateral extrusion of bone fragment. This lateral extrusion lead to fibulocalcaneal impingement and irritation of the peroneal tendon sheath which is the most common cause of pain at the lateral aspect of hind foot. In our study, extensile lateral approach was used for all cases and thick flap was raised along with incision to avoid the common wound problems encountered with the extensile approach especially in smokers and patients with diabetes. This approach was familiar, easy, simple, rapid, and adequate for the reduction and fixation of the posterior facet; it also allowed for the insertion of bone graft and reduction of the lateral wall. And also, it was easier to visualize the far medial fracture of the posterior facet and to address the displaced medial wall fracture through this approach.

Hammesfahr and Fleming [11], as well as Paley and Hall [20], reported better outcomes in patients who had a tongue type fracture than in those who had a joint depression fracture. They added that moderate comminution of the joint depression fractures worsened the prognosis, and extensively comminuted fractures were associated with the worst prognosis. In our study type II and type III fractures had excellent to good results, type IV fractures had fair to bad results. We also found the more comminuted the fracture, the more unsatisfactory the results. One patient with poor result had type IV fractures, while majority of patients (32%) with excellent results had type II fractures.

All the patients irrespective of age and Sander's types were taken up after 10-14 days for surgery to allow the edema to subside and the skin status to improve. Because the post op wound dehiscence is one of the major complications in our study, subsidence of edema is important before taking the patient for surgery. Tourniquet application, restricted surgical time, soft tissue handling, arising thick flap along with incision, postoperative crepe bandage application & limb elevation minimizes the wound dehiscence.

Standard lateral, axial, and internal oblique radiographs are adequate for the assessment of the subtalar joint. Oblique radiographs of

foot were valuable for addressing the extension of fracture into the calcaneo cuboid joint. Preoperative CT scan was useful for analysis of the fracture and planning; this helped to reduce surgical time and soft tissue morbidity Preoperative CT scan with 3D reconstruction is essential to plan the number & positioning of the screws, need of bone graft depending on the comminution. However, it is of less value in postoperative assessment because of interference by the metallic implants.

We found a strong correlation between the restoration of normal anatomy (congruity of the subtalar joint, Bohler's angle, calcaneal height and width, as assessed radiologically) and a satisfactory functional outcome. Stephenson [26] concluded that anatomical reduction of calcaneus is essential to achieve good result. Leung et al. [15] found a significant correlation between the radiological assessment and the clinical findings with regard to the subtalar joint. Paley and Hall [20] stated that Bohler's angle is an indirect reflection of both calcaneal height and the arch angle; a small Bohler's angle is associated with a poor result. This implies that preservation of the calcaneal height and arch angle is important. In McReynolds' series [18], in which the feet were immobilized in a plaster cast postoperatively, the motion of the subtalar joint at follow-up was 25% of normal in 90% of patients. In Stephenson's series [26], in

which secure fixation was accomplished from the lateral side and early motion instituted, the average subtalar motion at follow-up was 75% of normal. In our study, ankle joint and subtalar joint mobilisation were started earlier at an average of three weeks. At average of 11 months of follow up 92% of patients had normal ankle movements and 76% of patients had normal subtalar movements. Remaining 24% of cases (Sander's type III & IV) with post operative subtalar incongruency, had restriction of subtalar movements. 95% of people had gone back to the original progression.

In our series the anatomical reduction, subtalar congruity, Bohler's & Gissane's angle, calcaneal height & width were well achieved postoperatively using calcaneal tentacle plate. Maintenance of Subtalar congruity and calcaneal height & width are essential to make the patient to walk in uneven surfaces without pain and to get good post operative inversion and eversion of foot [13, 14]. Any post osteosynthesis subtalar joint incongruence would give poor result with early secondary arthritis (21) and painful inversion-eversion movements. In our series, congruence of subtalar joint was achieved in 76% of cases.

In most of our cases the Bohler's & Gissane's angles were well maintained compare to other series (30, 31). Post operative Bohler's angle

collapse complication is mainly due to lateral thalamic fragment partial necrosis, which was minimized in our study by taking thick flap during incision.

Post operative collapse at the fracture site can be prevented by using rigid fixation with adequate screws, using bone graft in severely comminuted fractures, delayed weight bearing. *Three areas of dense cortical bone will hold fixation well*- distal portion of the calcaneus (near the calcaneo cuboid joint), below the angles of Gissane (below the posterior facet, into the sustentaculum tali), the calcaneal tuberosity.

The success is mainly because of rigid tentacle plate kept the fragment in good position [(33)] and avoiding the early load bearing also important in preventing collapse. In this series minimum time taken for partial weight bearing was 2 months & for full weight bearing was 3 months. Depending upon the fracture pattern, comminution, anatomical reduction & fixation the weight bearing was started. Weight bearing was started earlier (8 wks) in those cases with type-II fractures, good anatomical reduction & rigid fixation, without comminution,

The bone grafting in selected cases with severe comminution (type III & IV) also main reason for prevention of collapse as in Longino's report [32]. In our study, depending upon the severity of comminution,

bone grafting was used for 14 cases (56%). Bone grafting was mainly indicated for type III and type IV fractures.

In this series, one patient with type IV fracture had developed chronic osteomyelitis. That patient was managed with implant removal; daily dressing under antibiotic coverage and later on hindfoot arthrodesis was done.

Among 25 patients operated, 14 patients (56%) were very much satisfied, 10 (40%) were satisfied & 1(4%) had a poor result. All eight types II (32%) fractures had excellent result, anatomical reduction, normal subtalar congruency and none of them required bone grafting. In type III fractures, six out of 11 cases (24%) had excellent results, one case had subtalar incongruency and seven cases required bone grafting. In type IV fractures, five patients had good result & one patient had poor result, five patients had subtalar incongruency and six patients required bone grafting.

CONCLUSION

In Our study of 25 cases with Sander's type II, III & type IV calcaneal fracture, osteosynthesized with calcaneal tentacle plate and followed up for an average period of 11 months , 96% of cases had satisfactory results both functionally and radiologically. Further follow up is needed for long term results.

- The extended lateral approach accounts for low incidence of complication.
- After suitable interval to improve the soft tissue status, this series recommend to take the cases for surgery between 14 to 21 days from the time of injury.
- Wound dehiscence is the common complication, which can be minimized by raising cutaneous-subcutaneous flap during incision.
- Prevention of collapse is mainly by the rigid fixation & perfect anatomical plating and delayed weight bearing.
- Bone grafting is needed for severely comminuted cases.

- We systematically obtained anatomical reduction, whatever the Sanders type. This reconstruction and subtalar joint congruence, essential for a good result.

- Post operative subtalar joint incongruence may lead to early subtalar arthritis, which can be managed with subtalar arthrodesis.

- Osteosynthesis of type II calcaneal fractures give excellent result compared to other fracture patterns.

- In case of contra-indication relating to age, associated pathology such as diabetes or arteriopathy, or psychiatric disturbance, we advise plaster cast immobilization for relatively congruent fractures, and closed percutaneous pinning or screwing for more displaced and incongruent fracture.

Proper pre-operative planning, rigid fixation with calcaneal tentacle plate and adequate screws through extensile lateral approach, anatomical reduction to achieve subtalar joint congruency, using bone grafts in comminuted fractures, early post op rehabilitation, delayed weight bearing will give good results in case of displaced intra articular calcaneal fractures.

CASE ILLUSTRATION

Case I ***: 17 Yr/ Male***

Diagnosis ***: Right side calcaneal fracture***

Sander's type ***: Type II***

Pre-Op Bohler's angle ***: 20^{o}***

Pre-Op Calcaneal height ***: 44 mm***

Procedure ***: open reduction & internal fixation with***

Calcaneal tentacle plate (medium size).

Bone grafting ***: Not done***

Post-Op Bohler's angle ***: 28^{o}***

Post-Op Calcaneal height: 56 mm

Follow up ***: 1 Year***

Complications ***: Nil***

Weber's Score ***: Excellent***

CASE – I
A: 17 Yrs. / Male

PREOP X-RAYS

PREOP CT

POSTOP X-RAYS

3 MONTHS FOLLOW UP

1 YEAR FOLLOW UP

MOVEMENTS

Case II ***: 38 Yr/ Female***

Diagnosis ***: Right side calcaneal fracture***

Sander's type ***: Type III***

Pre-Op Bohler's angle ***: 15^{o}***

Pre-Op Calcaneal height ***: 42 mm***

Procedure ***: open reduction & internal fixation with***

Calcaneal tentacle plate (medium size).

Bone grafting ***: Not done***

Post-Op Bohler's angle ***: 22^{o}***

Post-Op Calcaneal height: 52 mm

Follow up ***: 1 year 8 months***

Complications ***: Nil***

Weber's Score ***: Excellent***

CASE – II

S: 38 Yrs. / Female

POSTOP X-RAYS

PREOP X-R

1 YEAR FOLLOWUP

MOVEMENTS

Case III ***: 60 Yr/ Male***

Diagnosis ***: Right side calcaneal fracture***

Sander's type ***: Type III***

Pre-Op Bohler's angle ***: 20^{o}***

Pre-Op Calcaneal height ***: 44 mm***

Procedure ***: open reduction & internal fixation with***

Calcaneal tentacle plate (medium size).

Bone grafting ***: Not done***

Post-Op Bohler's angle ***: 32^{o}***

Post-Op Calcaneal height: 52 mm

Follow up ***: 2 years***

Complications ***: Nil***

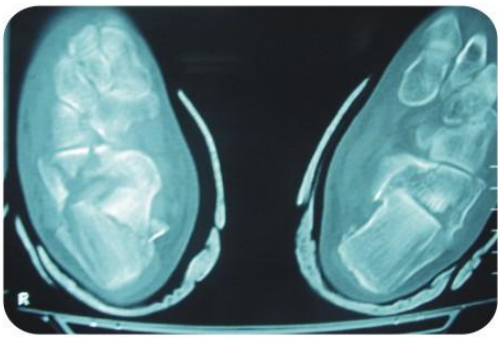
Weber's Score ***: Excellent***

CASE – III

J: 60 Yrs. / Male

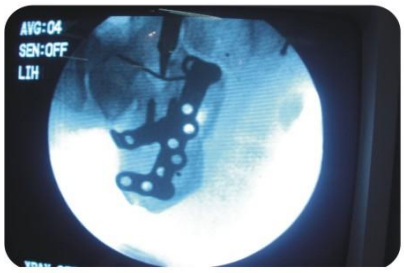
PREOP X-RAYS

PREOP CT



INTRAOPERATIVE

C-ARM IMAGES



2 YEARS FOLLOW UP

Case IV ***: 58 Yr/ Male***

Diagnosis ***: Right side calcaneal fracture***

Sander's type ***: Type III***

Pre-Op Bohler's angle ***: 15^{o}***

Pre-Op Calcaneal height ***: 38 mm***

Procedure ***: open reduction & internal fixation with***

Calcaneal tentacle plate (medium size).

Bone grafting ***: Not done***

Post-Op Bohler's angle ***: 24^{o}***

Post-Op Calcaneal height: 54 mm

Follow up ***: 1 year 5 months***

Complications ***: Wound dehiscence***

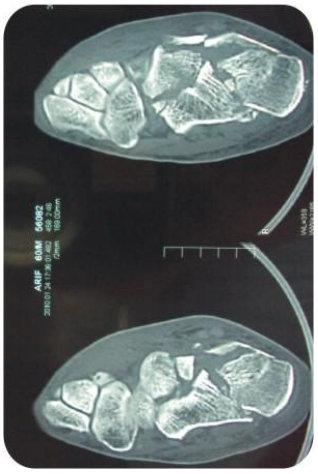
Weber's Score ***: Excellent***

CASE – IV

B: 58 Yrs. / Male

PREOP X-RAYS

PREOP CT



POSTOP X-RAYS

6 MONTHS FOLLOW UP

1 YEAR FOLLOW UP

MOVEMENTS

Case V ***: 42 Yr/ Male***

Diagnosis ***: Right side calcaneal fracture***

Sander's type ***: Type II***

Pre-Op Bohler's angle ***: 20^{o}***

Pre-Op Calcaneal height ***: 45 mm***

Procedure ***: open reduction & internal fixation with***

Calcaneal tentacle plate (medium size).

Bone grafting ***: Not done***

Post-Op Bohler's angle ***: 30^{o}***

Post-Op Calcaneal height: 52 mm

Follow up ***: 2 years***

Complications ***: Nil***

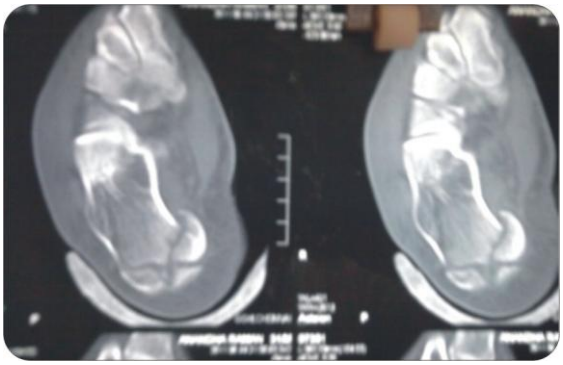
Weber's Score ***: Excellent***

CASE – V

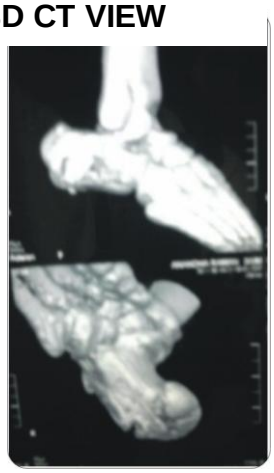
Q: 42 Yrs. / Male

PREOP X-RAY

PREOP CT



3D CT VIEW



POSTOP X-RAY

MOVEMENTS

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MASTER CHART

Name IP No.	Age	Sex	Sander's Type	Pre-op Bohler's	Post-op Bohler's	Bone Grafting	Calcaneal Height Pre-op	Calcaneal Height Post-op	Post op subtalar congruence	Radiological Union	Complications	Weber's Scoring
A 70288	17	M	Type II	20^{o}	28^{o}	No	44mm	56mm	congruent	++	NIL	Excellent
B 1552	58	M	Type III	15^{o}	24	No	38mm	54mm	congruent	++	Wound Dehiscence	Excellent
C 83488	23	M	Type II	18^{o}	26	Yes	36mm	48mm	Congruent	++	NIL	Excellent
D 69270	25	F	Type II	20^{o}	26	Yes	38mm	46mm	Congruent	++	NIL	Excellent
E 78617	28	M	Type III	17^{o}	24	No	41mm	55mm	Congruent	++	NIL	Excellent
F 84631	32	M	Type IV	$<10^{o}$	20	No	31mm	48mm	Congruent	++	NIL	Good
G 77796	18	F	Type IV	$<10^{o}$	18	Yes	28mm	46mm	Incongruent	Non Union	Chr. Osteomyelitis, subtalar restriction	Bad
H 66198	38	M	Type III	14^{o}	22	Yes	42mm	55mm	Congruent	++	Wound dehiscence	Good
I 22947	20	F	Type II	17^{o}	24	Yes	39mm	48mm	Congruent	++	NIL	Excellent
J 56082	60	M	Type II	20^{o}	32	No	44mm	52mm	Congruent	++	NIL	Excellent
K 72358	29	M	Type IV	$<10^{o}$	20	Yes	39mm	48mm	Incongruent	++	Subtalar Restriction	Good
L 75684	45	M	Type III	12^{o}	20	Yes	37mm	46mm	Congruent	++	Wound dehiscence	Good

M 77205	26	M	Type IV	<10°	20	Yes	32mm	44mm	Incongruent	++	Subtalar Restriction	Good
N 69298	40	M	Type III	16°	24	No	38mm	45mm	Congruent	++	NIL	Excellent
O 61392	18	M	Type III	<10°	20	Yes	36mm	44mm	Incongruent	++	Subtalar Restriction	Good
P 09460	27	M	Type III	14°	24	Yes	38mm	47mm	Congruent	++	NIL	Excellent
Q 86163	42	M	Type II	20°	30	No	45mm	52mm	Congruent	++	NIL	Excellent
R 06965	28	M	Type III	12°	20	Yes	43mm	55mm	Congruent	++	Ankle Restriction	Good
S 843221	38	F	Type III	15°	22	No	42mm	52mm	Congruent	++	NIL	Excellent
T 61972	24	M	Type IV	<10°	22	Yes	26mm	48mm	Incongruent	++	Subtalar Restriction	Good
U 56973	52	M	Type III	15°	22	Yes	41mm	53mm	Congruent	++	Ankle Restriction	Good
V 72963	38	M	Type III	16°	26	No	44mm	53mm	Congruent	++	NIL	Excellent
W 800903	42	F	Type II	18°	32	No	43mm	50mm	Congruent	++	NIL	Excellent
X 77337	36	M	Type IV	<10°	20	Yes	34mm	44mm	Incongruent	++	Subtalar Restriction	Good
Y 91452	40	F	Type II	18°	28	No	46mm	52mm	Congruent	++	NIL	Excellent

Modified Weber rating scale: (Annexure – 1)

Elements of the scale:

a. Subjective: (Annexure -1 A)

1. Pain	**Score**
1. None	**0**
2. Slight pain with excess activity	**1**
3. Mild pain with normal activity	**2**
4. Pain with standing	**3**
5. Pain at rest	**4**

2. Walking	**Score**
1. Normal	**0**
2. Restricted in strenuous activities	**1**
3. Slight limp	**2**
4. Partially disabled	**3**
5. Totally disabled	**4**

3. Activity	**Score**
1. Full at work and sport	**0**
2. Can work normally but is restricted in some Activities	**1**
3. Normal work but very limited in activity	**2**
4. Partially disabled	**3**
5. Totally disabled, must change job	**4**

B. objective: (Annexure -1B)

1. Radiographs	**Score**
1. Anatomical restoration & no progression of arthritis	**0**
2. Slight progression	**1**
3. Considerable progression	**2**

2. Ankle joint function	**Score**
1. Full, equal to other side	**0**
2. Loss of movement 10^0 or less	**1**
3. Loss of motion > 10^0 but dorsiflexion of 95^0 possible	**2**
4. 5^0 dorsiflexion possible	**3**
5. Stiff ankle	**4**
3. Subtalar joint function	**Score**
1. Full, equal to other side	**0**
2. Slight diminution	**1**
3. Limitation <50^0 compared to other side	**2**
4. Limitation >50^0	**3**

Score 2 – 8 Excellent

Score 9-15 Good

Score 16-21 Bad

Annexure –2:

Scoring system for posterior subtalar joint

Grade	Articular Incongruity (mm step off)	Arthritic changes
0	0-1	None
1	1-2	Slight joint space narrowing
2	2-3	Marked joint space narrowing, osteophyte formation
3	>3	Bone-on bone, osteophyte formation, cyst formation